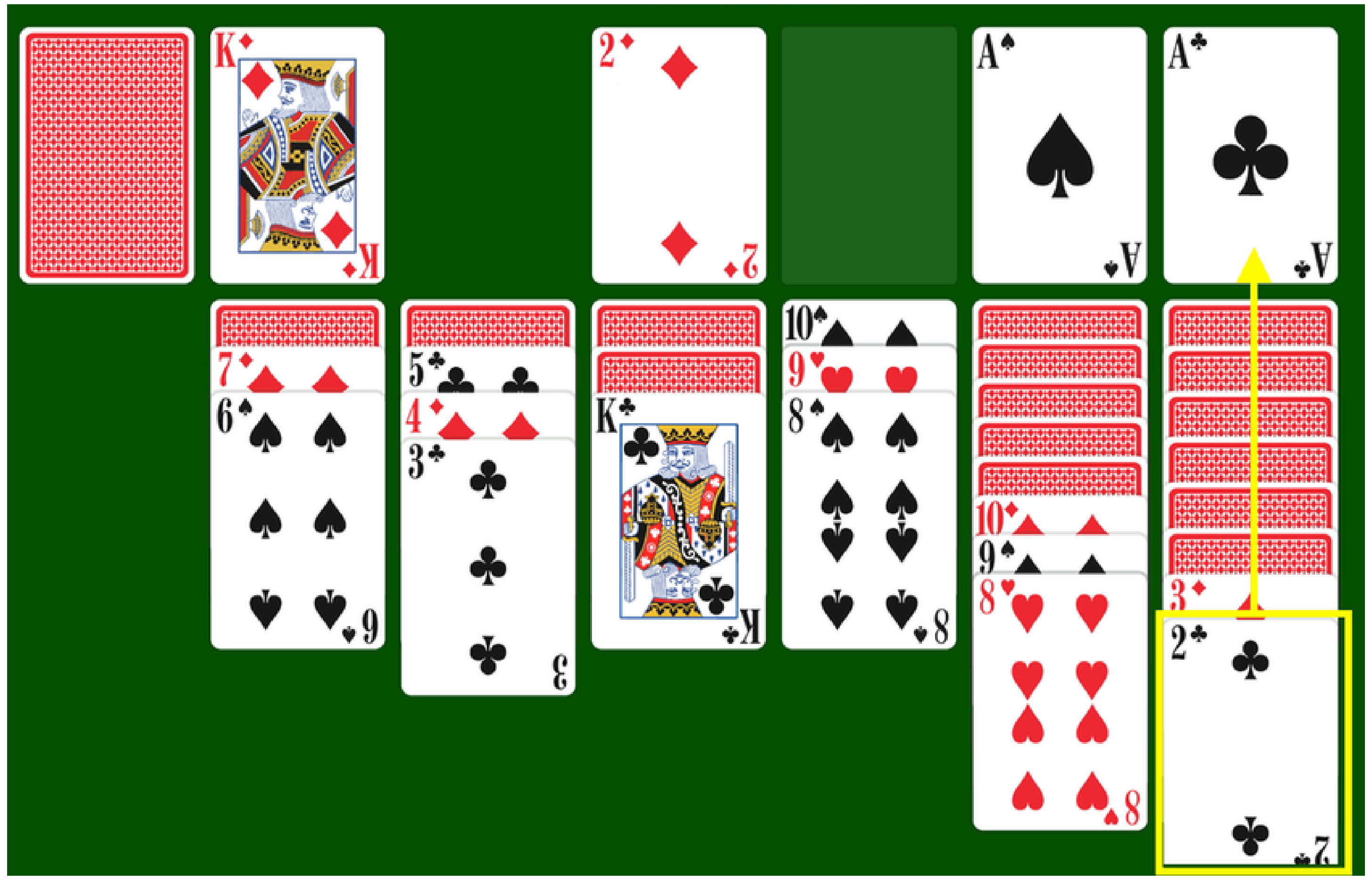

Solitaire

Man Versus Machine

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Introduction

In this paper, we use the rollout method for policy improvement to analyze a version of Klondike solitaire. This version, sometimes called thoughtful solitaire, has all cards revealed to the player, but then follows the usual Klondike rules. A strategy that we establish, using iterated rollouts, wins about twice as many games on average as an expert human player does.

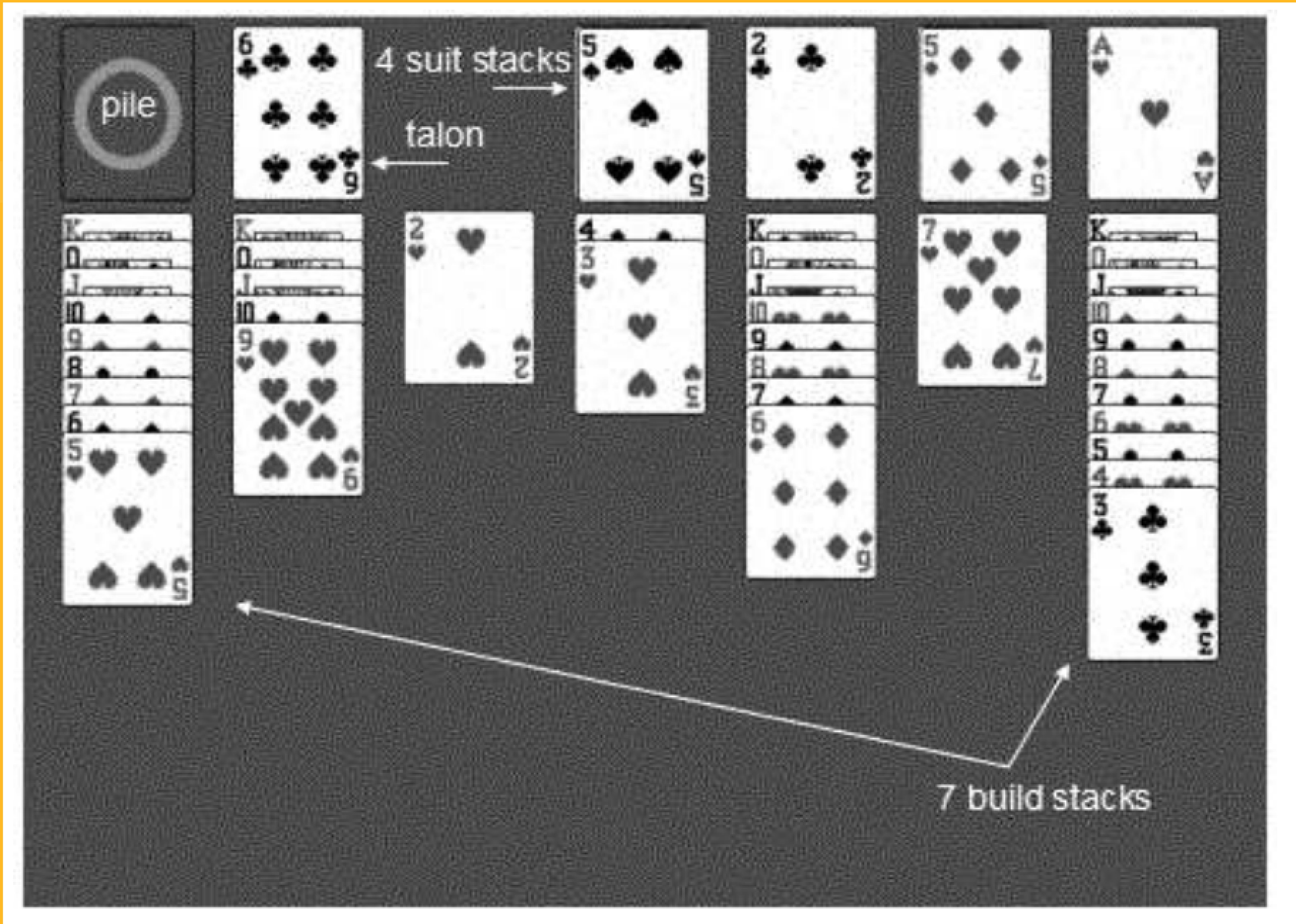
About The Game

Klondike is played with a standard deck of cards: there are four suits (Spades, Clubs, Hearts, and Diamonds) each made up of thirteen cards ranked 1 through 13: Ace, 2, 3, ..., 10, Jack, Queen, and King. During the game, each card resides in one of thirteen stacks : the pile, the talon, four suit stacks and seven build stacks. Each suit stack corresponds to a particular suit and build stacks are labeled 1 through 7.

At the beginning of the game, cards are dealt so that there is one card in the first build stack, two cards in the second build stack, ..., and seven cards in the seventh build stack. The top card on each of the seven build stacks is turned face-up while the rest of the cards in the build stacks face down. The other twenty-four cards, forming the pile, face down as well. The talon is initially empty

The goal of the game is to move all cards into the suit stacks, aces first, then two's, and so on, with each suit stack evolving as an ordered increasing arrangement of cards of the same suit.

The Figure shows a midway configuration of the game.



Basic Rules

Face-up cards of a build stack, called a card block, can be moved to the top of another build stack provided that the build stack to which the block is being moved accepts the block

The top face-up card of a build stack can be moved to the top of a suit stack

The top card of a suit stack can be moved to the top of a build stack

A card on the top of the talon can be moved to the top of a build stack or a suit stack.

A build stack can only accept an incoming card block if the top card on the build stack is adjacent to and braided with the bottom card of the block

Scoring System

1. The player starts the game with an initial score of 0.

2. Whenever a card is moved from a build stack to a suit stack, the player gains 5 points.

3. Whenever a card is moved from the talon to a build stack, the player gains 5 points.

4. Whenever a card is moved from a suit stack to a build stack, the player loses 10 points.

The Problem

It is one of the embarrassments of applied mathematics that we cannot determine the odds of winning the common game of solitaire.

What is the chance of winning?
How does this chance depend on the version I play?
What is a good strategy?

A Heuristic Strategy

We Select a move that maximizes the score and assign zero to the move not covered in scoring system.

To select among the moves that maximizes the score we break tie by assigning the following priorities.

1: Card is moved from build stack to another build stack

a.*Let k be the number of originally face-down card. So, if the move turns and face-down card face-up it gets a priority of k+1*
b.If the moves empty the stack priority of 1 is assigned.

2: Card is moved from talon to build stack

a.*If card moved is king the priority is 1*
b.If card moved is king and matching queen is in the pile or talon or suit stack or face-up in build stack the priority of 1 is assigned.
c.If card moved is king and its matching queen is face-down in build stack the priority of -1 is assigned.

3: For any card move not covered above we assign a priority of Zero.

Rollouts

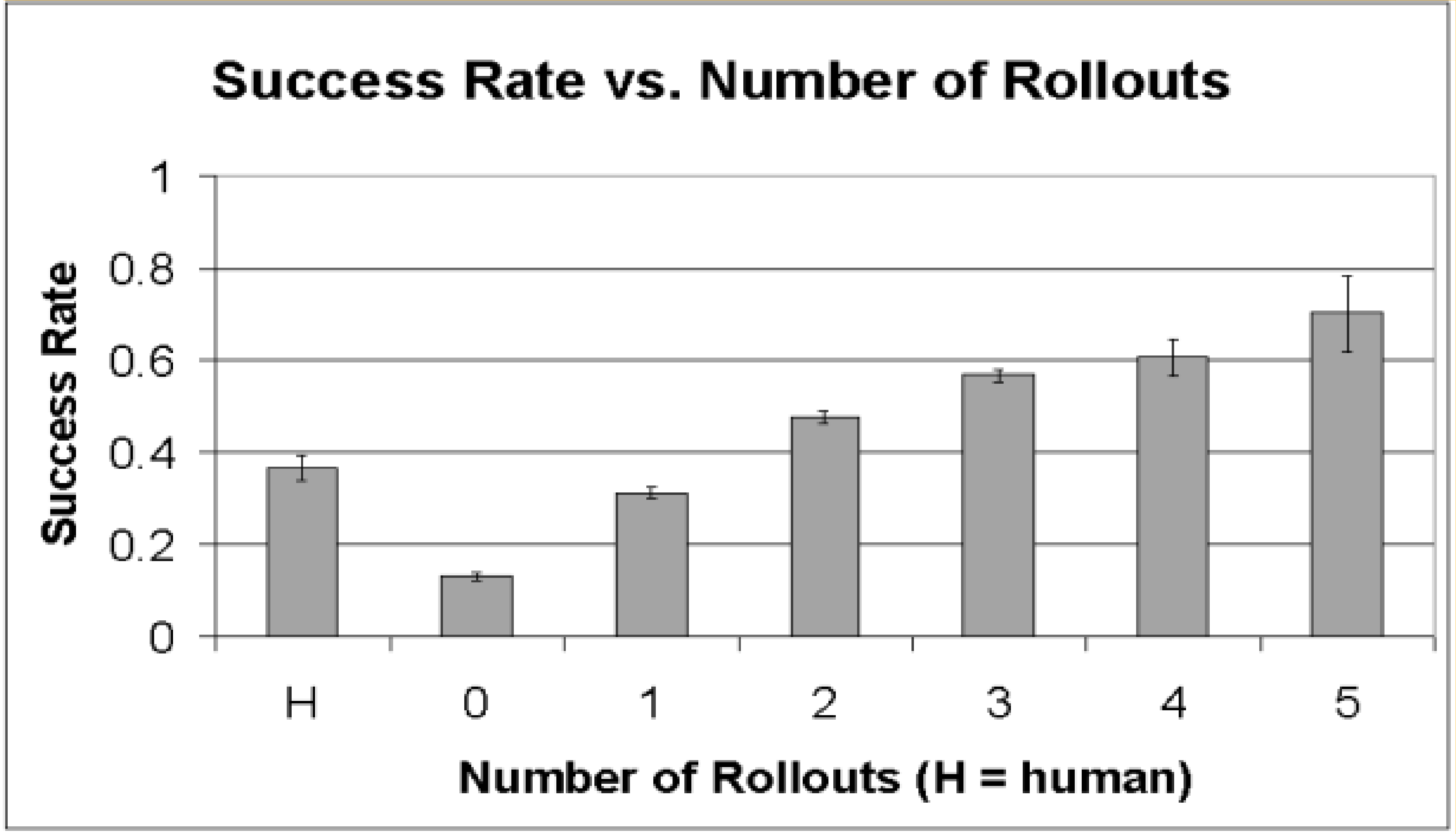
Consider a strategy h that maps a card configuration x to a legal move h(x).

Given a strategy h, this procedure generates an improved strategy h', called a rollout strategy

THE ROLLOUT STRATEGY IS DETREMINED AS FOLLOWS:

1. For each legal move a, simulate the remainder of the game, taking move a and then employing strategy h thereafter.
2. If any of these simulations leads to victory, choose one of them randomly and let h'(x) be the corresponding move a.
3. If none of the simulations lead to victory, let h'(x) = h(x).

Results



Player	Success Rate	Games Played	Average Time Per Game	99% Confidence Bounds
Human expert	36.6%	2,000	20 minutes	±2.78%
heuristic	13.05%	10,000	.021 seconds	±.882%
1 rollout	31.20%	10,000	.67 seconds	±1.20%
2 rollouts	47.60%	10,000	7.13 seconds	±1.30%
3 rollouts	56.83%	10,000	1 minute 36 seconds	±1.30%
4 rollouts	60.51%	1,000	18 minutes 7 seconds	±4.00%
5 rollouts	70.20%	200	1 hour 45 minutes	±8.34%

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